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TESTS OF A GLASS FIBER CHANNEL LINER

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CONTENTS

	Page
Introduction	3
Methods and materials	3
Layout	3
Preparation of channels and application of treatments	5
Testing and observing procedure	7
Results	7
Performance of liners	8
East channel	8
Reach A	8
Reach B	8
Reach C	8
Reach D	8
West channel	10
Reach A	10
Reach B	10
Reach C	11
Reach D	11
Bed erosion	11
Permissible velocity	13
Retardance coefficient	13
Conclusions	14

TESTS OF A GLASS FIBER CHANNEL LINER [1]

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INTRODUCTION

Newly constructed earth channels need temporary protection from water erosion until a protective cover of vegetation can be grown. Once the vegetation is established, adequate protection is afforded to channels commonly used to convey runoff from agricultural lands, highways, airports, and similar areas to outlet disposal points. The extensive use of vegetation-lined waterways coupled with increased labor costs has prompted a search for methods and materials to aid in the establishment of these waterways. Temporary liners that would not interfere with plant growth and at the same time would protect the new waterways from eroding and gullying by small but frequent flows would reduce establishment problems and maintenance costs. Among a number of materials proposed for temporary channel liners is glass fiber.

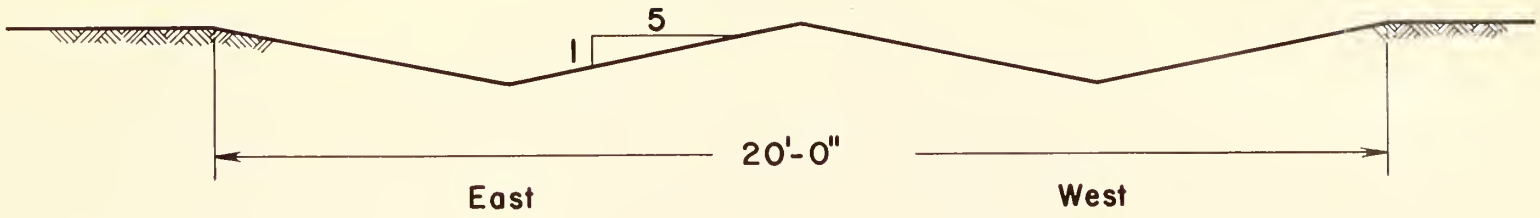
A channel liner of glass fiber roving was tested at the Stillwater Outdoor Hydraulic Laboratory to determine the liner's ability to protect an earth channel. The flow retardance coefficient was also determined. The glass fiber was tested alone and in combination with other treatments intended to improve its protective characteristics. The auxiliary treatments were a sprayed asphalt application used to bind the glass fiber strands together and to the earth, a paper fiber material that acts as a mulch and light binder, and a combination of the asphalt spray and paper fiber. These treatments, the testing procedure, and the results of the tests are described.

METHODS AND MATERIALS

Layout

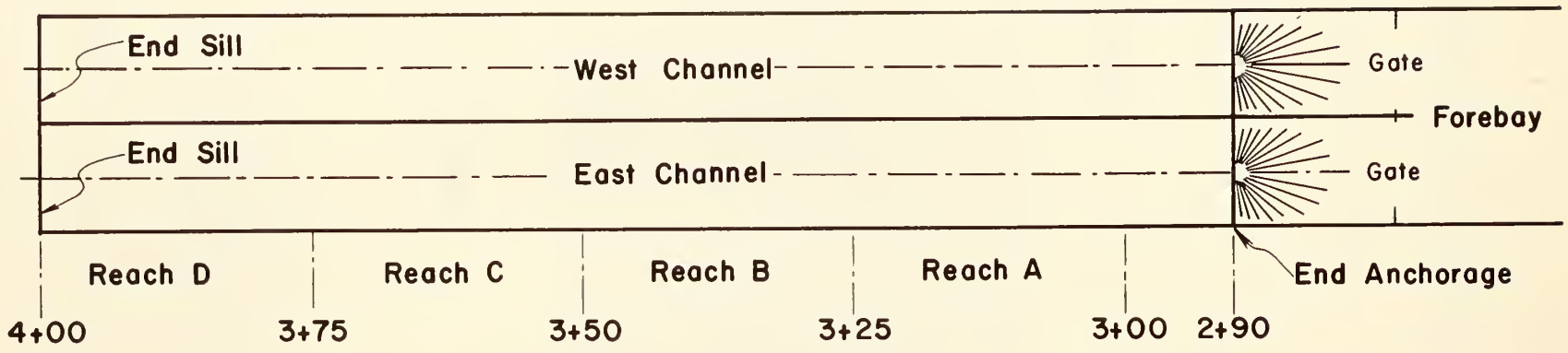
The tests were conducted in two adjacent V-shaped channels, each having a 10-foot top width, 1 on 5 side slopes, and a 6-percent bottom slope. The arrangement is shown in figure 1. Each channel consisted of an entrance section, 10 feet of shaped approach channel, a 100-foot test length, and an end sill so that erosion below the free outfall would not travel upstream into the test section. The two 100-foot test channels were divided into four 25-foot reaches designated

[1] In cooperation with the Oklahoma Agricultural Experiment Station.



CHANNEL CROSS SECTION

NOTE:
Channel slope = 0.06



PLAN

Figure 1.--Layout for channel liner experiment.

A, B, C, and D. A different lining was placed in each reach. This meant that each reach could not be subjected to exactly the same test since the uppermost reach would receive relatively clear water and the lower reaches would receive some sediment from above along with the water. Although the erosion rates would be somewhat affected, the liners would not be affected by the light debris from upstream but only by the quantity of water flowing. The tests were exploratory and the general information yielded by the experimental procedure would be useful. The arrangement chosen would produce the maximum amount of useful information from the available space and time. The upper three reaches were used as test reaches from which quantitative data were obtained. Special profilers at the end of reaches A, B, and C were used to obtain flow depth and cross-section measurements. Only qualitative observations were obtained from reach D.

Water for the tests was conducted through a system of canals from the laboratory supply to the test channels. A type-H measuring flume located near the channels measured the discharge. A flow diversion scheme was used whereby the flow could be diverted from one channel to the other quickly and easily, or the test channels could be completely bypassed. Thus, it was possible to set a discharge, test one channel for a controlled duration, test the other for a controlled duration, and then immediately shut off the flow to the test channels by bypassing all flow.

Preparation of Channels and Application of Treatments

The test channels were shaped to subgrade cross section in the pebbly, tight clay subsoil of the site. A sandy-clay fill, 2 to 3 inches deep, was then placed on the channels and shaped to the finished cross section. This fill material was easily eroded and thus provided a more severe test of the protective qualities of the liner than would the clay subsoil. While the 2- to 3-inch fill may seem small, it was sufficient to provide a meaningful test, since erosion depths as great as 3 inches on a freshly seeded channel represent severe damage.

The glass fiber was supplied as a roving (individual glass fibers slightly twisted together into a loose twine or rope) wound into a ball much as is baler twine. It was applied by running the loose end of the roving through a tubelike applicator where a blast of air expanded and ejected the roving from the tube. The ejected roving looked much like a stream of low-velocity water from a hose. The glass fiber was applied by a workman who directed the stream to cover the ground at the desired application rate. Application was made at 50 percent and 100 percent of the manufacturer's recommended rate of 35 pounds per 150 square yards. Figure 2 shows the glass fiber being applied.

The glass fiber was tested with a water spray set, an asphalt spray, a slurry of short paper fiber, or various combinations of an asphalt spray and a slurry of short paper fiber, as listed in table 1. The water spray was used to pound the expanded glass fiber down to the soil and to prevent blowing; the asphalt acts as a binding agent; the paper fiber acts as a mulch and light binder.

Before the treatments were applied, a small trench was dug 10 feet upstream from the upper end of each test channel.

Figure 2.--Application of glass fiber to east test channel.

TABLE 1.--Treatments and performance[1]

Channel	Reach	Treatment[2]				Results		
		1 Glass fiber	2 Asphalt spray	3 Paper fiber slurry	4 Water spray	Order of application	Discharge at partial failure	Discharge at complete failure
		Lb./150 sq. yd.				Col. No.	C.f.s.	C.f.s.
East	A	35	X	----	----	1, 2	2.1	4.3
East	B	35	X	X	----	1, 2, 3	2.1	4.3
East	C	35	----	X	----	1, 3	1.1	2.1
East	D	35	----	----	X	1, 4	---	.2
West	A	35	X	X	----	1, 3, 2	1.1	2.1
West	B	35	X	----	X	1, 2, 4	1.1	2.1
West	C	35	X	----	----	2, 1, 2	1.1	2.1
West	D	17.5	X	----	----	1, 2	.2	.5

[1] See accompanying description for additional information.
[2] All applications were made onto a dry, raked soil surface.

When the treatments were applied, the glass fiber was extended into this trench. Backfilling with earth formed an end anchorage for the material. The glass fiber was also extended upstream to the entrance gates and covered with asphalt spray to protect the entrance sections.

The treatments were completed in one afternoon. The asphalt was allowed to become firm (through evaporation of the lighter constituents) overnight. The tests were started the next morning.

Testing and Observing Procedure

Prior to introducing the first flow into the test channels, channel bed measurements were made to the earth beneath the liner at 1/2-foot intervals across the profile stations. Then the first test flow, about 0.2 cubic foot per second, was turned into one channel and allowed to run for 40 minutes. Flow depth measurements were made shortly after the flow had stabilized and again shortly before the flow was cut off. At the end of the 40-minute test period the water was abruptly diverted and the channel bottom measurements were repeated. The channel and liner were observed and, if they were not excessively damaged, the flow was approximately doubled and another 40-minute test was run. The testing procedure was continued until the last intact reach of each channel and liner were destroyed. The quantitative and visual observations were supplemented with movies and still photographs of the channel taken both during and after the tests. Figure 3 shows a typical test.

Figure 3.--West channel, test 2.

RESULTS

The results are presented in four sections: Performance of liners, bed erosion, permissible velocity, and retardance coefficients.

The tandem arrangement of four treatments in one channel resulted in the lower reaches being affected by the occurrences in the upper reaches. Therefore when the quantitative data in table 2 (see p. 12) are examined any conclusions should be tempered by the observations presented in the section on the performance of liners.

Performance of Liners

East Channel

Reach A.--Glass fiber roving was applied at the rate of 35 pounds per 150 square yards onto the dry, raked soil surface. Then sufficient asphalt spray was applied to cover the roving (fig. 4a). The asphalt spray was rather thick and resulted in a blobby, spotty covering of the glass fiber.

During all tests the liner floated and allowed scour beneath. The scoured material moved downstream and affected the scour rates in the downstream reaches. The liner remained intact until the fifth test when it completely washed out at a discharge of 4.3 cubic feet per second (figs. 4b and 4c).

Figure 4a.--Before testing.

Figure 4b.--After fourth test flow, Q = 2.1 c.f.s.

Figure 4c.--After fifth test flow, Q = 4.3 c.f.s.

Reach B.--Glass fiber roving was applied at a rate of 35 pounds per 150 square yards onto a dry, raked soil surface. Asphalt was then sprayed on the roving, followed by a slurry of paper fiber (fig. 5a). The asphalt spray was rather thick and the coverage was uneven.

The liner performed much the same as did the liner in reach A--floating during all tests and allowing scour beneath. The liner remained intact until the fifth test when it completely washed out at a discharge of 4.3 cubic feet per second (figs. 5b and 5c).

Reach C.--Glass fiber roving was applied at a rate of 35 pounds per 150 square yards onto a dry, raked soil surface. Then a paper fiber slurry was applied (fig. 6a).

During the first two tests, reach C caught much of the erosion debris from reaches A and B. The third test discharge disturbed the liner, causing two debris dams and rough flow. Parts of the liner were displaced downstream as can be seen in figure 6b. The fourth test discharge carried away the center of the liner and the reach was considered a failure. Its appearance was similar to figure 6c.

Reach D.--The glass fiber roving was applied at the rate of 35 pounds per 150 square yards onto a dry, raked soil surface. The roving was then set with water (fig. 7a).

The first test flow displaced the liner and exposed the soil to the erosive force of the water. The reach was considered to have failed (fig. 7b).

Figure 5a.--Before testing.

Figure 5b.--After fourth test flow, $\underline{Q}$ = 2.1 c.f.s.

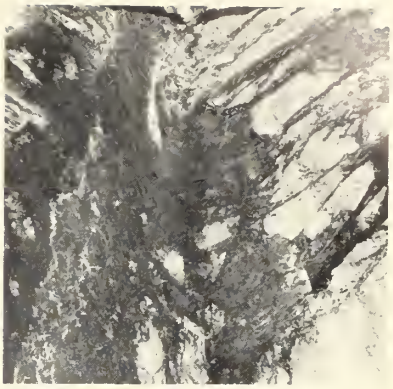


Figure 5c.--After fifth test flow, $\underline{Q}$ = 4.3 c.f.s.

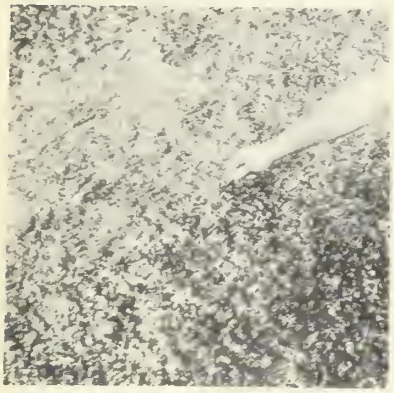


Figure 6a.--Before testing.

Figure 6b.--After third test flow, $\underline{Q}$ = 1.1 c.f.s.

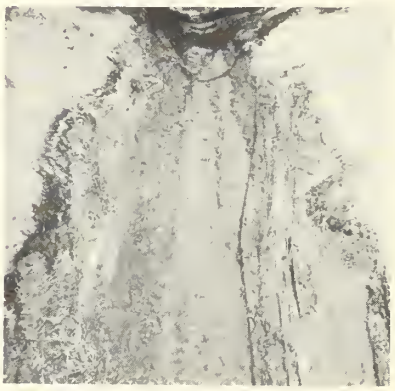


Figure 6c.--After fifth test flow.

Figure 7a.--Before testing.

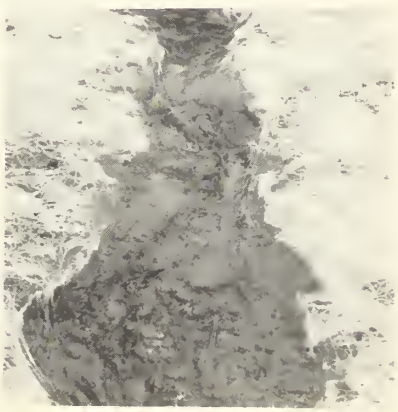


Figure 7b.--After first test flow, $\underline{Q}$ = 0.2 c.f.s.

West Channel

Reach A.--Glass fiber roving was applied at a rate of 35 pounds per 150 square yards onto a dry, raked soil surface. A paper fiber slurry was applied, followed by an asphalt spray (fig. 8a). The asphalt spray used on the west channel was smoother than that used on the east channel and a better cover was obtained on all reaches.

The liner floated in the first 10 to 15 feet of the reach during the first two tests and allowed scour beneath. The scoured material moved downstream to either deposit in the lower reaches or possibly reduce scouring in them. The liner loosened and displaced downstream during the third test (fig. 8b). The center of the liner was carried away by the fourth test flow and the reach was considered a failure (fig. 8c).

Reach B.--The glass fiber roving was applied at the rate of 35 pounds per 150 square yards. Asphalt spray was applied followed by a water spray (fig. 9a).

The rate of erosion shown in table 2 (p. 12) indicates that reach B caught erosion debris from reach A during the first test. The second test discharge pulled the center of the liner into small folds which caused a roughening of the flow. The center of the liner loosened and matted during the third test (fig. 9b). The fourth test discharge carried away the sides and bottom of the liner (fig. 9c).

Figure 8a.--Before testing.

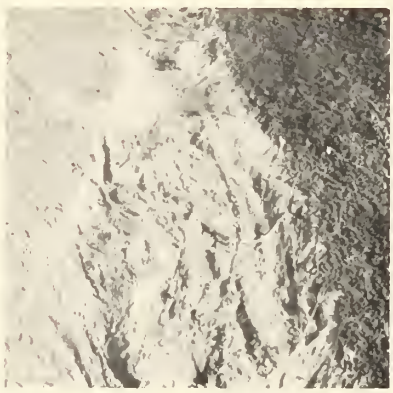


Figure 8b.--After third test flow, $\underline{Q}$ = 1.1 c.f.s.

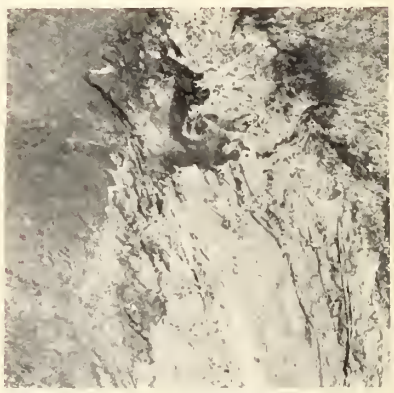


Figure 8c.--After fourth test flow, $\underline{Q}$ = 2.1 c.f.s.

Figure 9a.--Before testing.

Figure 9b.--After third test flow, $\underline{Q}$ = 1.1 c.f.s.

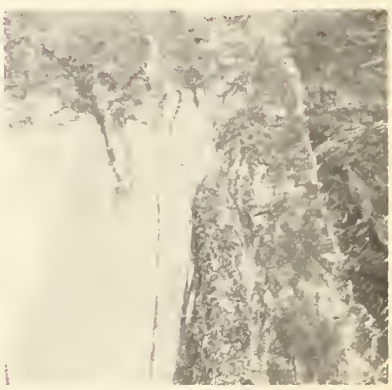


Figure 9c.--After fourth test flow, $\underline{Q}$ = 2.1 c.f.s.

Reach C.--Sufficient asphalt spray was applied to cover the ground, a dry, raked soil surface. Glass fiber roving was then applied at the rate of 35 pounds per 150 square yards, followed by another application of asphalt spray (fig. 10a).

Reach C behaved much the same as did reach B. Reach C caught erosion debris during the first test and showed little visual evidence of erosion during the second test; the bottom portion loosened and matted during the third test (fig. 10b). The fourth test flow carried away the sides and bottom of the liner (fig. 10c).

Reach D.--Glass fiber roving was applied at the rate of 17.5 pounds per 150 square yards, one-half the normal rate. This was followed by an asphalt spray sufficient to cover the roving (fig. 11a). The channel coverage was rather poor.

The first test flow caused some apparent scour in this reach (fig. 11b). During the second test the liner failed in the center, pulling some of the material on the sides into the stream (fig. 11c).

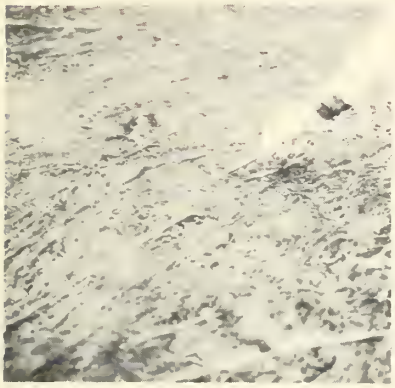


Figure 10a.--Before testing.

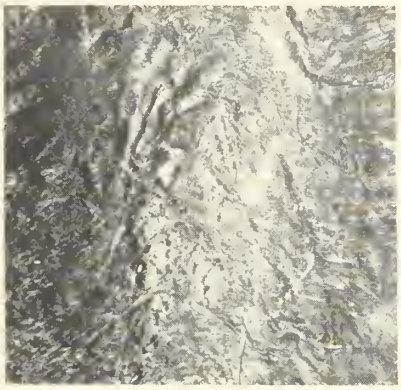


Figure 10b.--After third test flow, $\underline{Q}$ = 1.1 c.f.s.

Figure 10c.--After fourth test flow, $\underline{Q}$ = 2.1 c.f.s.

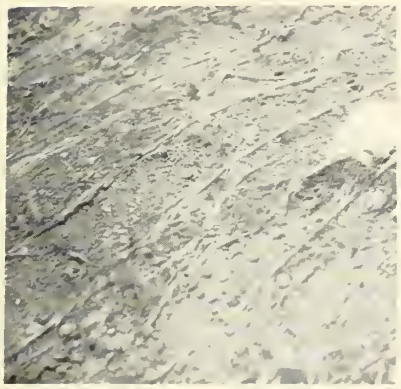


Figure 11a.--Before testing.

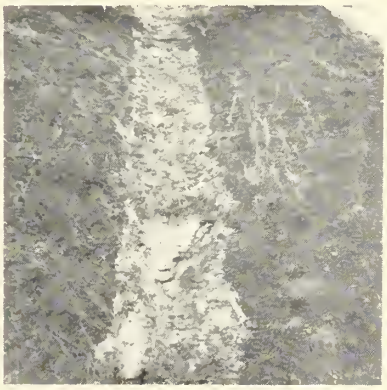


Figure 11b.--After first test flow, $\underline{Q}$ = 0.2 c.f.s.

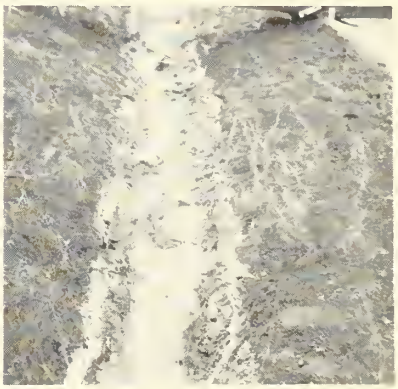


Figure 11c.--After second test flow, $\underline{Q}$ = 0.5 c.f.s.

Bed Erosion

The cross-section data taken from before and after each test were used to calculate the erosion rate for each reach of channel. The erosion rates are presented in table 2. An explanation of the sequence of events is required in order to interpret these data. Initially the upper reaches eroded and the water could carry but little more sediment when it came to the lower reaches.

TABLE 2.--Summary of data on erosion tests of glass-fiber liner

Channel and reach	Test	Discharge	Velocity	Manning coefficient	Rate of erosion
East channel:		C.f.s.	F.p.s.		In./hr.
A	1	0.194	1.56	0.041	1.215
	2	.524	4.23	.026	.391
	3	1.14	3.75	.026	.434
	4	2.09	3.32	.035	[1] .298
	5	4.34	3.76	.036	[2] .530
B	1	.194	1.16	.062	.306
	2	.524	3.30	.026	.532
	3	1.14	3.25	.033	.966
	4	2.09	3.93	.033	[1] .677
	5	4.34	4.17	.037	[2] .595
C	1	.194	1.18	.060	.245
	2	.524	2.82	.046	.963
	3	1.14	2.93	.037	[1] 1.168
	4	2.09	3.84	.031	[2] .527
	5	4.34	3.93	.038	.375
D	1	.194	----	----	([2])
	2	.524	----	----	-----
	3	1.14	----	----	-----
	4	2.09	----	----	-----
	5	4.34	----	----	-----
West channel:					
A	1	.214	----	----	.096
	2	.522	1.60	.058	.714
	3	1.14	1.83	.066	[1] -.650
	4	2.10	2.22	.063	[2] .157
B	1	.214	1.69	.031	-.544
	2	.522	1.76	.047	.618
	3	1.14	2.34	.044	[1] .159
	4	2.10	2.80	.046	[2] -.186
C	1	.214	1.84	.030	-.200
	2	.522	2.16	.039	.730
	3	1.14	3.10	.034	[1] 1.071
	4	2.10	4.24	.028	[2] .535
D	1	.214	----	----	([1])
	2	.522	----	----	([2])
	3	1.14	----	----	-----
	4	2.10	----	----	-----

[1] Partial failure.
[2] Complete failure.

These lower reaches either caught the erosion debris from the upper reaches or yielded little material, depending upon whether the water slowed down or speeded up. The deposition of material eroded from upstream reaches is the explanation of the negative erosion rates shown in table 2. As the discharge increased, more material eroded from the upper reaches and some of the material in the lower reaches also eroded. The upper reaches finally eroded to the hard subsoil in the bottom of the channel after which most of the erosion took place in the lower reaches. Thus, the peak erosion rates took place at a later test for the lower reaches than for the upper reaches.

Permissible Velocity

One measure of the protective ability of a channel liner is the flow velocity it can withstand before excessive scour of the channel bed occurs. The determination of this permissible velocity was one of the objectives of these tests.

The planned procedure to determine the permissible velocity was to increase the discharge rate for each successive test to obtain higher velocities. These velocities were to be compared with the rate of erosion of the channel bed to see if a relation existed. Also sought was the velocity that marked the beginning of excessive erosion. This velocity then would be the maximum allowable--the safe or permissible velocity.

A study of the data in table 2 shows no consistent relation between velocity and rate of erosion. Some of the reasons for this are explained in the previous section. Furthermore, larger discharge rates did not always yield higher velocities. In some instances the explanation for this anomaly can be found in the increased Manning's n value due to roughening of the channel bed. In other instances no explanation for the anomaly could be discovered. Because of these inconsistencies it is not possible to establish a permissible velocity based on the velocity-erosion relation.

Retardance Coefficient

The retardance coefficient n was calculated for each reach for each test by the Manning formula:

$$n = \frac{1.486}{Q} A R^{2/3} S^{1/2}$$

The area (A) was an average of the reach end areas measured at the beginning and end of each test. The hydraulic radius (R) was computed using the average area and an average wetted perimeter. The energy line slope (S) was computed using the end-of-reach velocity heads and water surface elevations. Q is the total discharge.

Examination of the data in table 2 shows considerable variation in the Manning retardance coefficient. This variation was caused by folds and debris dams in the channel bottom, floating of the liner, and by the complete washing out of the liner in some reaches. The retardance coefficient was highest for reach A of the west channel where flow emerged from beneath the liner within the reach. For the smooth intact liner, the Manning coefficient was approximately 0.03.

CONCLUSIONS

1. Application of the glass fiber roving at the rate of 35 pounds per 150 square yards may have some usefulness for light duty protection of newly established earth waterways. Whether or not it can be used in any particular situation can be determined only after a cost-benefit comparison analysis.

2. Application of glass fiber roving at the rate of 17.5 pounds per 150 square yards is unsatisfactory for protecting channels.

3. Asphalt is necessary to bind the glass fiber into a mat.

4. Paper fiber material has no value as a binder. Its value as a mulch was not investigated in this study.

5. The Manning coefficient value for intact, asphalted liner is 0.03.

6. The Manning coefficient for an eroded, roughened channel with flow beneath the liner ranges from 0.026 to 0.066.

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